



## 4.1 Criteria for Evaluating Priorities

Society confronts Earth system science issues that are remarkable for their diversity of topics, complexity of interactions, and ranges of spatial and temporal scales—a vast array of initiatives offers potential contributions. NASA seeks to select research with the highest potential to improve our understanding of the Earth system while addressing critical societal questions. Optimum return from NASA's investments in Earth observations and research, measured in terms of objective information and scientific answers with societal relevance, is obtained when scientific value leads in setting priorities.

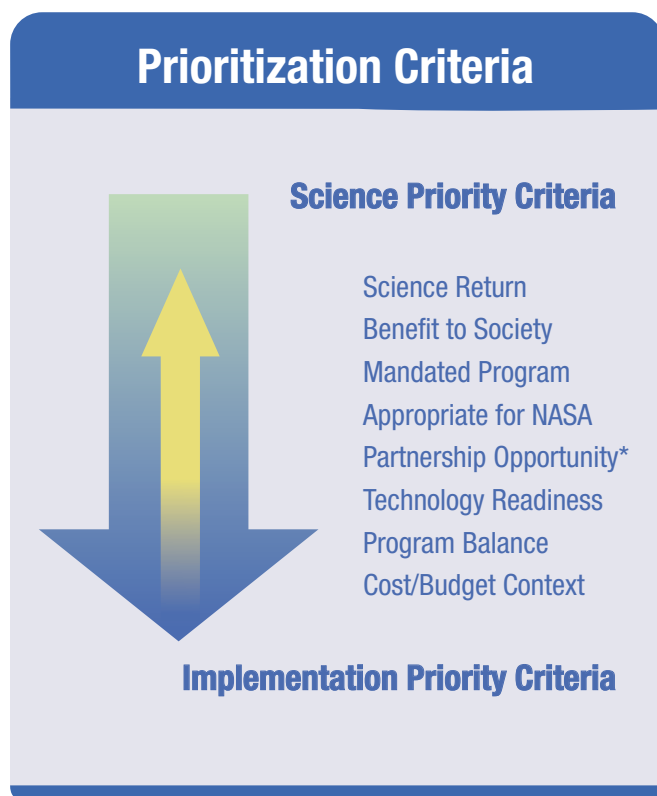
Establishing research priorities across disciplines each embracing a large set of scientific questions is a major challenge. NASA balances competing demands in the face of available resources and technology to chart a program that addresses the most important and tractable scientific questions making optimal use of NASA's unique capabilities for global observation, modeling, analysis, and basic research. Thus, NASA's research priorities reflect both scientific requirements and implementation realities. Scientific considerations are paramount and drive the prioritization process by defining science questions and ultimately by determining potential projects. But context and implementation issues can alter priority to address benefits to society, mandates, or relevance to NASA's roles. Technological feasibility shapes the order in which projects are pursued and the final shape they may take. These practical considerations often result in feedback and iteration of project selection.

Figure 4.1 summarizes criteria for setting research priorities within the NASA Earth science research. The criteria are not ordered by importance in all cases; rather, they are presented in order of procession as project concepts are conceived and matured. Application of these criteria may vary with specific



circumstances, especially given the nature of the question being investigated and the mission potentially being or project being considered.

Figure 4.1



#### 4.1.1 Scientific Return

Scientific return is judged by the perceived significance of the problem being addressed in the overall scheme of Earth system science and anticipated technological advances toward providing definitive results. Scientific return is often high for innovative investigations that break into unexplored scientific territory. In other instances, major scientific advances are achieved only through systematic analyses of vast bodies of observations, as is often the case in the study of complex systems like the Earth. Experience demonstrates that maximum scientific return is obtained when research and observing program initiatives are conceived and designed to address specific science issues or questions. Finally, scientific priority also depends on the logical progression in approaching a complex scientific problem. Identifying the significant elements of variability in the Earth system and trends in forcing factors provides a necessary foundation for deeper insight into response mechanisms. Likewise, investigation of the consequences and the development of robust prediction methods

requires a priori knowledge of the operative processes. The NASA Earth science research program represents an appropriate balance between the different steps of this progression. The potential for amplification of the Earth's response to forcing variations is an element of this choice (e.g., the positive feedback associated with changes in the distribution of atmospheric water vapor).

#### 4.1.2 Benefit to Society

The degree to which initiatives address scientific questions of importance to society is an important measure of their benefit. Thus, the NASA structures its research plan and project priorities for Earth science around a hierarchy science questions with strong societal relevance. But observations and data products can have direct value as well and this affects the priority for underlying research. For example, better measurements may improve weather or natural hazard predictions to society's benefit short of contributing significant new understanding of the processes involved. An element of choice in selecting research programs is the potential for continuing infusion of relevant data for applications purposes. Typically, however, improved measurements and understanding go hand-in-hand.

#### 4.1.3 Mandated Programs

Congressional direction imposes research priorities recognized as benefiting society. Specific budget guidance through the appropriations process can set research priorities. For example, recently Congress directed NASA to increase research on the global carbon cycle and atmospheric CO<sub>2</sub> increases. As specified by NASA's Authorization Act and by the Clean Air Act, the agency is required to maintain a research, monitoring, and technology development program for atmospheric ozone surveillance and associated atmospheric chemistry. NASA is also required to report to Congress and the Environmental Protection Agency every third year on the status of knowledge of atmospheric ozone and the abundance of ozone-depleting substances in the atmosphere.

#### 4.1.4 Appropriate for NASA

NASA shares with other CCSP partners an interest in fundamental studies of the basic processes that govern the Earth system, diagnostic studies of recent and past data records, and model simulations/predictions of global changes. At the same time, effective use of resources requires that the NASA's Earth science strategy be focused on research projects that allow optimal use of NASA's unique capabilities. Compared to the range of investigations embraced by the entire CCSP, NASA's Earth science program emphasizes measuring changes



in forcing parameters, and documenting the natural variability of the Earth system and responses to forcings, especially through space-based measurements that can provide global coverage, high spatial resolution, and/or temporal resolution, in combinations which cannot be achieved by conventional observational networks.

Choosing among all potentially important research questions is a judgment of scientific value. In the context of NASA's Earth science research program, the principal scientific priority criteria are the spatial scale, temporal duration, and magnitude of the phenomena being investigated, as well as anticipated return in term of reducing the uncertainty in our knowledge of potential changes in the Earth system.

Research questions that address Earth system dynamics at large regional to global scales are those of greatest interest for NASA. Questions that involve smaller scale changes that have the potential to be of global significance if aggregated over a sufficiently large number of areas, are also relevant. Similarly time scales that range from seasonal, through decadal to long-term are of primary interest to NASA. This is particularly true for regions where only limited conventional (non-space) observations are available (e. g. the atmosphere over the open ocean and polar regions; continental ice sheets). For example, NASA research in atmospheric chemistry has been focused on global scale chemical processes rather than local air quality (which is typically the responsibility of regulatory environmental agencies).

Likewise preference is given to the study of phenomena and processes that may induce lasting changes in the Earth system, typically seasonal and longer period responses, as well as changes that are irreversible in the foreseeable future. Understanding and predicting fast processes (e. g. the development of weather systems, trace gas emissions) may be essential in order to quantify longer-term average impacts. While forecasting individual environmental events is not a primary NASA objective, further developing the technology for experimental prediction of specific events (e.g., weather disturbances) that can be verified by observation is a fundamental research tool for understanding changes in climate and the global environment (e. g. mean displacement in storm tracks). At the process level, priority is given to those processes that have the potential to induce large time/space scale impacts and/or are the root of large uncertainty in the overall response of the Earth system.

NASA has a very strong commitment to the use of its observational data in scientific research, and invests in the development of models and global data assimilation systems

that can be used for the analysis and interpretation of observations from NASA programs and other relevant observing networks, as well as for the development of improved forecasting capability related to answering the questions posed in this plan. NASA's earth science research program also has a robust sub-orbital component, which is focused on improving our understanding of processes needed to understand, interpret, and model remotely sensed observations, as well as to contribute to the calibration and validation of the space-based observations. Innovative combinations of observing instruments and platforms are used in this component of the program.

#### 4.1.5 Partnership Opportunity

NASA conducts Earth science research within a larger national and international context. This implies both opportunities for task sharing with partner agencies and the responsibility to seek optimal coordination of mutually supportive programs of these national and international partners. In particular, NASA has been actively seeking the cooperation of operational agencies in the US (through the National Polar-Orbiting Operational Environmental Satellite System, NPOESS) and elsewhere to ensure the long-term continuity of key environmental measurements in the long term. To achieve this goal, NASA will promote the convergence of the operational observation requirements of partner agencies with its research data needs for systematic observations, share the cost of new developments, and develop precursor instruments and spacecraft technologies for future operational application missions. NASA will also encourage the continuing involvement of scientific investigators in the calibration and validation of operational measurements, the development of more advanced information retrieval algorithms, and the analysis of operational data records. From this perspective, the potential for serving operational needs or commercial-applications is a priority criterion for NASA Earth science programs.

Interagency and international partnerships are also important for maximizing the scientific value of any research while minimizing costs. The need for partnerships in process-oriented field measurement activities is crucial, especially when investigators' access to particular regions of scientific interest is needed. For space-based measurements, partnerships provide the opportunity for leveraging additional contributions onto those that would be made by NASA, and allow for benefiting from the technological and scientific skills resident in other agencies and countries, as well as access to information needed for validation under a broad range of biological and geophysical conditions. Partnership opportunities will typically be encouraged in all relevant solicitations as long as they



are consistent with national policy objectives such as export control of sensitive technology. Commercial partnerships also provide the opportunity for NASA to obtain needed data or services, and NASA has committed to working with the private sector to avoid duplicating capability that already exists in it.

#### 4.1.6 Technology Readiness

For observation projects in particular, a key criterion in determining the timing and order of selection is the readiness of the relevant technology. In some cases additional technological investments are required over the past and current years in order to demonstrate the possibility of making this measurement from space. For instance, lidar wind measurements were possible a decade ago, but only at an unacceptable cost for development and operations. Recent and ongoing work indicates the potential for design of a space-based system at a cost comparable to current programs, and perhaps even implementation as a commercial data purchase. NASA implements technology development programs relevant to each stage of the instrument maturation process (e.g., components, instrument design, flight demonstration). Parallel programs in spacecraft and information technologies are pursued to assure overall mission feasibility.

#### 4.1.7 Program Balance

The hallmark of NASA's Earth science program is the synergy between different classes of observations, basic research, modeling, and data analysis, as well as field and laboratory studies. In particular, when engaging in pioneering research about complex scientific issues, the ESE recognizes the need for complementary remote sensing and in situ measurements. Nonetheless, the strategic decisions that define the ESE program in the long term are those, which affect the space flight mission element, involving the longest lead-time and largest investment of resources. From both a programmatic and a scientific research strategy perspective, the ESE distinguishes three types of space flight missions: systematic observation missions, exploratory missions, and operational precursor or technology demonstration missions. The identification of these categories represents a significant departure from the original architecture of the Earth Observing System, which combined studying basic processes, assembling long-term measurement records, and introducing innovative measurement techniques. The distinction between these classes of missions facilitates a sharper definition of primary mission requirements, and clearer selection criteria, ultimately leading to a shorter development cycle and more cost-effective implementation. Priority criteria will be considered separately

for the research and analysis program and the separate categories of missions.

#### 4.1.8 Cost/Budget Context

Ultimately NASA's budget constrains its Earth science research efforts. The suite of activities the agency undertakes must be consistent with budget lines. But financial resources depend on scientific rationale and societal benefit that derive from a balanced Earth Science program. Once established, the negotiated (or anticipated) budget becomes a criterion that may drive iteration for many projects back up the criterion ladder to some level.

### 4.2 National and International Planning, Coordination, and Collaboration

To address the broad requirements of numerous government, public, and private organizations around the world for improved Earth observations and understanding of the Earth system, NASA participates in an array of national and international planning and coordination activities related to Earth science and the environment. Much of NASA's Earth science research is focused on the goals and requirements of four major U.S. programs: (1) the Climate Change Science Program (CCSP), (2) the Climate Change Technology Program (CCTP), (3) the U.S. Weather Research Program (USWRP), and (4) Interagency Working Group on Earth Observations (IWGEO). These broad programs provide important frameworks for U.S. research addressing environmental change as well as for weather and natural hazard prediction.

**U.S. Climate Change Science Program (CCSP).** NASA Earth science research is aligned with the Climate Change Science Program involving 13 agencies seeking to address two fundamental questions:

- How will variability and potential change in climate and related systems affect natural environments and our way of life?
- How can we use and improve this knowledge to protect the global environment and to provide a better living standard for all?

To address these questions, the CCSP organizes long-term research within seven program elements: (1) Atmospheric Composition, (2) Climate Variability and Change, (3) Global Carbon Cycle, (4) Global Water Cycle, (5) Ecosystems, (6) Land Use or Land Cover Change, and (7) Human Contributions and Responses. Within NASA, Earth science research is organized under six focus areas corresponding closely with these CCSP program elements.



**U.S. Weather Research Program (USWRP).** The overarching goal of the USWRP is to improve high-impact weather forecasting capability at an accelerated pace. Particular emphasis is on better forecasts of the timing, location, and specific rainfall amounts of hurricanes and flood events that significantly affect the lives and property of U.S. inhabitants. Satellite observations, for example of tropical rainfall, are critical to reaching this goal as are improved systems for assimilating remote sensing data within models used for weather prediction.

**U.S. Interagency Working Group on Earth Observations (IWGEO).** A Declaration of the Earth Observation Summit of 33 nations and the European Commission in July, 2003 calls for a comprehensive, coordinated, and sustained Earth observing system or systems to: monitor continuously the state of the Earth; increase understanding of dynamic Earth processes; enhance prediction of the Earth system; and further implement environmental treaty obligations. Responding to this comprehensive goal, an intergovernmental Group on Earth Observations (GEO) is developing a 10 year plan for an integrated Earth observation system. The U.S. IWGEO coordinates the observing plans of U.S. Federal agencies and provides the U.S. input to the international GEO plan. NASA looks to this decadal planning activity to articulate many of the challenges and goals for the next major stages in Earth remote sensing, assimilation of observations, and prediction of variations and change within the Earth system.

NASA seeks mutually beneficial cooperation in Earth science research with other nations and groups of nations. In order to study the diverse components of global change, data with global scope and coverage are required. Phenomena across the planet must be observed, modeled, and understood. Regional observations and experiments as well as the participation of regional experts in the process of discovery are essential. Recognizing this inherently international character of Earth science, NASA has cooperative agreements for joint

or coordinated Earth science research with over 60 nations that range from data sharing to collaborative development of remote sensing research satellites. Additionally, NASA participates in the major international programs in Earth science.

**International Geosphere-Biosphere Programme (IGBP).** With current focus on biogeochemistry, the IGBP delivers scientific knowledge to help human societies develop in harmony with Earth's environment. The program's scientific objective is to describe and understand the interactive physical, chemical and biological processes that regulate the total Earth System, the unique environment that it provides for life, the changes that are occurring in this system, and the manner in which they are influenced by human actions. IGBP develops and nurtures common international frameworks for collaborative research based on agreed agendas, assembles essential databases, and synthesizes scientific results.

**World Climate Research Programme (WCRP).** Jointly sponsored by the International Council of Scientific Unions and the World Meteorological Organization, WCRP develops the fundamental scientific understanding of the physical climate system and climate processes needed to determine to what extent climate can be predicted and the extent of human influence on climate. The program encompasses studies of the global atmosphere, oceans, sea and land ice, and the land surface which together constitute the Earth's physical climate system.

Together with a number of other international programs and organizations, the IGBP and WCRP provide an important international framework within which NASA Earth science research participates for coordination, planning, and collaboration. NASA looks to IGBP and WCRP to provide forums for considering priorities and arranging cooperation in order to keep NASA Earth science research in synchrony with international efforts and those of specific regions and nations and to take maximum advantage of joint ventures.

